2013

Arkansas Water Resources Center Annual Technical Report, 2013

Arkansas Water Resources Center

ARKANSAS WATER RESOURCES CENTER | UNIVERSITY OF ARKANSAS

FUNDED BY U.S. GEOLOGICAL SURVEY 104B PROGRAM THROUGH THE NATIONAL INSTITUTES OF WATER RESOURCES

MSC PUBLICATION 102.2013

ARKANSAS WATER RESOURCES CENTER ANNUAL TECHNICAL REPORT FY2013

2014 July

Arkansas Water Resources Center Annual Technical Report FY 2013

E.E. Scott[1] and B.E. Haggard[2]

[1]Project Manager, Arkansas Water Resources Center
[2]Director and Associate Professor, Arkansas Water Resources Center, 201 Engineering Hall, Fayetteville, Arkansas, 72701 Corresponding author: awrc@uark.edu

This publication serves as the annual report to the U.S. Geological Survey regarding the projects and activities of the Arkansas Water Resources Center for FY 2013. This document provides summary information for each of the 104B projects funded: 1) Assessing nitrosamine precursors in drinking water treatment plants; 2) Improving surface water quality by reducing SOD and nutrients; 3) Fecal source characterization in select 303(d) listed streams in the streams in the Illinois River Watershed with elevated levels of *Escherichia coli*; 4) The effect of global climate change on algal biomass and total organic carbon concentrations in Beaver Lake; and 5) Economics of on-farm reservoirs across the Arkansas Delta Region: A conjunctive management approach to preserving groundwater and water quality. This publication also summarizes the Arkansas Water Resources Center's information transfer program, student involvement, notable awards and achievements, and publications of previous 104B projects.

Keywords: Arkansas Water Resources Center, 104B Program Funding, Information Transfer, Water Quality

Introduction

The Arkansas Water Resources Center is part of the network of 54 water institutes established by the Water Resources Research Act of 1964 and is located at the University of Arkansas at Fayetteville. Since its formation, the Arkansas Water Resources Center (AWRC) in cooperation with the US Geological Survey and the National Institutes for Water Resources has focused on helping local, state and federal agencies understand, manage and protect water resources within Arkansas. AWRC has contributed substantially to the understanding and management of water resources through scientific research and training of students. Center projects have focused on topics concerned with water quality of surface water and groundwater, especially non-point source pollution and sensitive ecosystems. AWRC helps organize research to ensure good water quality for Arkansas today and in the future.

The AWRC focuses its research on providing local, state and federal agencies with scientific data and information necessary to understand, manage, and protect water resources within Arkansas. AWRC cooperates closely with colleges, universities and other organizations in Arkansas to address the state's water and land-related issues, promote the dissemination and application of research results, and provide for the training of engineers and scientists in water resources. Each year, with support from USGS 104B program funding, several research faculty participate in AWRC projects with the help of students who gain valuable experience conducting environmental-related work across the state. AWRC research projects have studied irrigation and runoff, best management practices to reduce erosion and pollution, innovation in domestic wastewater disposal systems, ground water modeling and land use mapping, water resource economics, water quality, and ecosystem functions. The Center provides support to the sponsored water research by acting as a liaison between funding groups and the scientists, and then coordinates and administers grants once they are funded. Project management, reporting and water analyses are major areas of support offered to principal investigators. The AWRC has historically archived and will continue to archive reports of water resource studies funded by the 104B program or managed through the Center on its website (http://www.uark.edu/depts/awrc/index.html).

In addition, the AWRC sponsors an annual water conference held in Fayetteville, Arkansas each spring or summer, drawing over 100 researchers, students, agency personnel and interested citizens to hear about results of current research and hot topics in water resources throughout the state. Information dissemination through the annual conference is an important service provided by the Center and allows for the organization of specialty conferences and workshops, as well as information sessions on specific watersheds with local non-governmental organizations. The AWRC also co-sponsors short courses and other water-related conferences in the state and across the region.

The AWRC also maintains a technical library containing over 900 titles, many of which are available online. The Center staff are continuously updating the availability of reports online, which increases the distribution of historical research funded through the 104B program and managed by the water center. In addition, the University of Arkansas library also catalogues AWRC publications. This valuable resource is utilized by a variety of user groups including researchers, regulators, planners, lawyers and citizens.

Additionally, AWRC maintains a modern water quality laboratory that provides water analyses for researchers, municipal facilities, and watershed stakeholders. Anyone, including farmers and other citizens, can submit samples through the cooperative extension service. This laboratory is certified through the Arkansas Department of Environmental Quality for the analysis of surface and ground water.

The AWRC has a technical advisory committee made up of professionals from education institutions, environmental organizations, water supply districts, and government agencies throughout Arkansas. This committee has the opportunity to evaluate proposals submitted annually to the USGS 104B program, to recommend session topics included in the annual research conference, and to provide general advice to the AWRC Director and staff. The technical advisory committee is updated each year to find active members, which are interested in the Center's function and management of the 104B program.

Research Program Introduction

Each year, several researchers participate in USGS 104B projects funded through the Arkansas Water Resources Center (AWRC). This program provides an excellent opportunity to include students in research projects and aid the entry of future scientists in water and environmental-related fields. The research projects funded through the AWRC have studied irrigation and runoff, best management practices to reduce erosion and pollution, innovation in domestic wastewater disposal systems, ground water modeling and land use mapping, water resource economics, water quality, and ecosystem functions. The AWRC aims to support and fund the most competent and promising research proposals submitted by research faculty to the 104B program; the intent has been to facilitate the collection of seed data to researchers such that larger proposals can be developed and submitted to extramural funding sources. As a result, AWRC has distributed 104B funds to several projects which have further secured extramural grants to continue the base research.

To formulate a research program relevant to state water issues, the Center works closely with state and federal agencies and academic institutions. An advisory committee, composed of representatives from government and non-government agencies, industry, and academia provides guidance for the Center. The technical advisory committee plays an important role in insuring that the water institute program (section 104) funds address current and regional issues. The priority research areas of the AWRC base program directly relate to the program objectives of the Water Resources Research Act, including research that fosters improvements in water supply, explores new water quality issues, and expands the understanding of water resources and water related phenomena.

In FY2013, the AWRC, under the guidance of the technical advisory committee, funded the following research projects: 1) "Assessing sources of nitrosamine precursors in drinking water treatment plants", Drs. Wen Zhang and Julian Fairey, University of Arkansas, Department of Civil Engineering, $17,500; 2) "Improving surface water quality by reducing SOD and nutrients", Dr. Gregory Osborn, University of Arkansas, Department of Biological and Agricultural Engineering, $7,200; 3) "Fecal source characterization in select 303(d) listed streams in the Illinois River watershed with elevated levels of *Escherichia coli*", Dr. Kristen Gibson, University of Arkansas, Department Food Sciences, $9,600; 4) "The effect of global climate change on algal biomass and total organic carbon concentrations in Beaver Lake", Drs. Byron Winston and J. Thad Scott, University of Arkansas, Department of Crop, Soil, and Environmental Sciences, $9,100; and 5) "Economics of on-farm reservoirs across the Arkansas Delta

Region: A conjunctive management approach to preserving groundwater and water quality", Drs. Kent Kovacs, Kristofor Brye, Jennie Popp, and Eric Wailes, Department of Agricultural Economics and Agribusiness and Department of Crop, Soil, and Environmental Sciences, $9,300.

Assessing Sources of Nitrosamine Precursors in Drinking Water Treatment Plants

Basic Information

Title:	Assessing Sources of Nitrosamine Precursors in Drinking Water Treatment Plants
Project Number:	2013AR341B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Treatment, Surface Water
Key Words:	Nitrosamines, disinfection by-product, drinking water treatment
Principal Investigators:	Wen Zhang and Julian Fairey

Publications and Presentations

1. Meints II, D., W. Zhang, and J. Fairey. 2014. Method development for a total N-Nitrosamine assay. Arkansas Water Works & Water Environment Association (AWW&WEA) Annual Meeting, Hot Springs, AR.
2. Meints II, D. 2014. Assessing biofilm-derived materials as nitrosamine precursors in drinking water treatment plants. MS Thesis, Department of Civil Engineering, University of Arkansas, Fayetteville, AR. (anticipated)

Arkansas Water Resources Center 104B Program Project – March 2013 through February 2014

Project Title: Assessing Sources of Nitrosamine Precursors in Drinking Water Treatment Plants

Project Team: Wen Zhang, Department of Civil Engineering, University of Arkansas, Fayetteville, AR
Julian L. Fairey, Department of Civil Engineering, University of Arkansas, Fayetteville, AR

Interpretative Summary:
Drinking water treatment plants (DWTPs) in the United States are facing a great challenge to achieve compliance with the Stage 2 Disinfection/Disinfection Byproduct (DBP) rule. When chloramine is used to curb formations of trihalomethanes (THMs) and haloacetic acids (HAAs), other DBPs, including highly toxic N-nitrosamines can form. This project aims to assess the relative contribution of the various N-nitrosamine precursors in drinking water systems. A total N-nitrosamine (TONO) assay was developed for drinking water systems, and used to demonstrate that biofilms formed in the water distribution systems can serve as precursors for total N-Nitrosamines.

Introduction:
There are 11 regulated disinfection byproducts (DBPs) in finished drinking water – 4 trihalomethanes (THMs), 5 haloacetic acids (HAAs), chlorite, and bromate. Formation of THMs and HAAs has been studied for decades and approaches have been adopted to limit their formation in treated water supplies (Krasner and Amy, 1995). However, other DBPs are now being considered for regulation, including compounds within the highly toxic N-nitrosamine family (Mitch et al., 2003), which is comprised of approximately 200 individual chemical species. N-nitrosamines form in drinking waters in highest concentrations during chloramination (Mitch and Sedlak, 2004), which is particularly concerning because many DWTPs have switched to chloramines in their distribution systems to limit THM and HAA formation. The objective of this project is to assess the relative contribution of the various N-nitrosamine precursors in drinking water systems. The work plan consists of the development of total nitrosamine (TONO) assay and assessment of a diverse group of N-nitrosamine precursors, including wastewater effluents, biofilms, and coagulant aids. The results will facilitate development of strategies to limit formation of N-nitrosamines in drinking water systems and help the DWTPs make informed decisions with regard to DBP control strategies.

Methods:
Total nitrosamine formation potential (TONOFP) with chloramines was measured using TONO assay following a technique developed by another research team (Kulshrestha et al., 2010). A diverse group of precursors in drinking water will be tested, including (1) raw water samples from three drinking water treatment plants – Beaver Water District (Lowell, AR), Mohawk Water Treatment Plant (Tulsa, OK) and A.B. Jewell Water Treatment Plant (Tulsa, OK), (2) wastewater effluent from West Side Wastewater Treatment Plant (Fayetteville, AR), (3) bacterial biofilms of three species (*Pseudomonas aeruginosa*, *Nitrosomonas europaea*, and *Staphylococcus epidermidis*) and biofilm-derived materials (alginate and chitin), and (4) coagulant aids, including polyDADMAC. Following a 10-day chloramination period required of the TONOFP tests, N-nitrosamines of different polarity were captured using continuous liquid-liquid extraction (CLLE) and solid phase extraction (SPE) before measurement in the TONO assay.

Results:
The TONO assay including the CLLE and SPE was successfully assembled (Figures 1 and 2) and the corresponding analytical method developed. TONO is measured by chemiluminescence following

conversion of all N-nitrosamine species to nitrogen oxide.

Figure 1: (A) TONO assay setup with liquid-liquid extraction apparatus; (B) TONO assay setup.

Figure 2: (A) Solid phase extraction setup; (B) Sample concentration apparatus.

Table 1 shows a summary of total N-nitrosamine measurement on various precursors. The TONO value is reported as ng/L of N-nitrosodimethylamine (NDMA), one widely occuring N-nitrosamine species. The established method achieved about 70% in the recovery of N-nitrosamines. All precursors shown in Table 1 yielded high TONO values, except for *N. europaea*. It is likely the low TONO from *N. europaea* was due to the salt inhibition in the growth media. Chitin and alginate represent purified forms of biofilm materials from different species (extracellular polysaccharides), and the high TONO formation suggests biofilm can serve as N-nitrosamine precursors in chloraminated systems.

Table 1: TONO measurement on various precursors.

Precursors		**TONO**
Pure Culture Bacteria	*P. aeruginosa*	High (~250 ng/L as NDMA)
	N. europaea	Low
Biofilm-Derived Material	Chitin	High (~300 ng/L as NDMA)
	Alginate	High (~200 ng/L as NDMA)

Conclusions:

Results to date indicate total N-nitrosamines measured by TONO assay is a suitable technique for assessing N-nitrosamine formations in drinking water, and biofilms in the chloraminated water distribution systems can serve as precursors for N-nitrosamines.

References:

Krasner, S. W. and Amy, G., 1995. Jar-test evaluations of enhanced coagulation. Journal American Water Works Association 87 (10), 93-107.

Kulshrestha, P., McKinstry, K. C., Fernandez, B. O., Feelisch, M. and Mitch, W. A., 2010. Application of an Optimized Total N-Nitrosamine (TONO) Assay to Pools: Placing N-Nitrosodimethylamine (NDMA) Determinations into Perspective. Environmental Science & Technology 44 (9), 3369-3375.

Mitch, W. A. and Sedlak, D. L., 2004. Characterization and fate of N-nitrosodimethylamine precursors in municipal wastewater treatment plants. Environmental Science & Technology 38 (5), 1445-1454.

Mitch, W. A., Sharp, J. O., Trussell, R. R., Valentine, R. L., Alvarez-Cohen, L. and Sedlak, D. L., 2003. N-nitrosodimethylamine (NDMA) as a drinking water contaminant: A review. Environmental Engineering Science 20 (5), 389-404.

Improving Surface Water Quality by Reducing SOD and Nutrients

Basic Information

Title:	Improving Surface Water Quality by Reducing SOD and Nutrients
Project Number:	2013AR342B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Water Supply, Water Quality, Treatment
Key Words:	SOD, algae, nutrients, TOC
Principal Investigators:	Gregory Osborn

Publications and Presentations

1. Richardson, G. 2014. Lab-scale Experiment for Assessing the Effect of Resuspension and Oxygenation on Sediment Oxygen Demand. MS Thesis, Department of Biological and Agricultural Engineering, University of Arkansas, Fayetteville, AR. (anticipated)

Arkansas Water Resources Center 104B Program Project – March 2012 through February 2013

Project Title: Improving Surface Water Quality by Reducing SOD and Nutrients

Project Team: Scott Osborn, Department of Biological and Agricultural Engineering, Division of Agriculture, University of Arkansas, Fayetteville, AR
Grace Richardson, Department of Biological and Agricultural Engineering, Division of Agriculture, University of Arkansas, Fayetteville, AR

Interpretative Summary:
Two studies were partially supported by these funds: testing the SDOX used for dissolved air flotation of algae in lab-scale tanks to removing nutrients from water; and testing resuspension and oxygenation of sediments from a eutrophic lake for reduction of SOD. The algae flotation experiment indicated that dissolved air flotation was able to remove chlorophyll A, B and C as well as total nitrogen, total phosphorus, and suspended solids from the water column. The average removal rates were, respectively, 23%, 24%, 64%, 12%, 28%, and 43%. Resuspension and oxygenation of sediment did not significantly reduce sediment oxygen demand any differently than resuspension alone. Sediment samples containing higher concentrations of metals did appear to have a slightly reduced SOD.

Introduction:
Surface waters containing excess concentrations of phosphorus and nitrogen are susceptible to forming algae blooms that can reduce water quality. The idea behind the algae flotation study is to use a new technology, SDOX (BlueInGreen, Fayetteville, AR) to perform dissolved air flotation in an open body of water such as a pond or lake to cause algae to move to the surface where it can be skimmed from the water. By removing algae, the nitrogen and phosphorus bound in the cells would be removed from the water. This study sought to determine if the SDOX technology was capable of floating the algae to the surface of several tanks in a greenhouse for removal and how much chlorophyll A, B, and C as well as total nitrogen, phosphorus and suspended solids were removed at different operating pressures of the SDOX. The greater the operating pressure, the greater the operating cost for the SDOX, so finding a workable setting at a minimum pressure is desirable.

The SOD reduction experiment was conducted because SOD is a critical factor responsible for the development of anoxic hypolimnia in eutrophic lakes and reservoirs. A reduction in SOD may not only delay or eliminate the onset of anoxia in the hypolimnia, but also potentially increase the depth of the oxic layer of sediment, allowing for greater binding of phosphorus (P) to oxidized metals. The proposed rapid resuspension method immediately exposes sediment to excess dissolved oxygen allowing oxygen-mediated chemical and biological reactions to proceed without being rate limited by oxygen availability. Current methods for oxygenation of sediments rely on oxygenation of overlying water and diffusion of oxygen into sediments. This process may create diffusion-limited rates of oxygen-mediated chemical and biological reactions within the intact sediment.

Methods:
For the algae flotation experiment, 9 glass tanks 270 L in volume were filled with dechlorinated water and spiked with nitrogen and phosphorus to target concentration of 1 mg/L TN and 0.1 mg/L TP. This produced eutrophic conditions in the water. Algae was seeded into the tanks and allowed to grow for 2 weeks. The

SDOX was operated at 3 pressures, 40, 65, and 90 psi and cycled for 1, 2, and 4 pulsed where a pulse is an injection of water supersaturated with air to produce microbubbles and cause flotation. After each pulse injection, the floated layer was manually skimmed. Each treatment was repeated for a total of 3x3x2 = 18 tests. The 9 tanks were tested, emptied, refilled and algae was grown again for a total of 18 tests. Water samples were collected before and after each treatment of both the treated water and the float layer removed. Chlorophyll A, B, and C were measured in addition to total nitrogen, total phosphorus, total solids, dissolved solids, and volatile solids.

For the SOD experiment, bottom sediments were collected from a local eutrophic water body, split into two samples, and then placed into 284 liter aquarium tanks. Sediment samples were resuspended for 3 hours, allowed to settle, resuspended for an additional 24 hours, allowed to settle, then resuspended for an additional 120 hours before being allowed to settle again. SOD was measured using a tank oxygen uptake slope from a DO meter as well as a core method. Also, fully suspended and aerobic mass-based sediment oxygen uptake rate (sedOUR), organic matter content, and sediment and water chemistry parameters were measured before and after each treatment time.

Results:
Algae was successfully floated and removed resulting in an average removal rate of 23% for chlorophyll A, 24% for chlorophyll B, 64% for chlorophyll C, 12% for total nitrogen, 28% for total phosphorus, and 43% for suspended solids. All samples from the skim layer contained significantly greater concentrations of all measured parameters indicating the flotation process was able to concentrate algae and nutrients into a removable layer. Sampling consistency was poor as it was difficult to mix the algae and water for proper distribution to collect a representative sample. The flotation process also appeared to flocculate some of the algae. This may lead to another study for an alternative removal procedure. The effect of SDOX operating pressure was not significant for chlorophyll A, B, total nitrogen, total phosphorus, and increased operating pressure increase removal rate for chlorophyll C and suspended solids.

SOD values throughout the test ranged from 140 to 1800 mg/m2-d. For SOD as measured in both tanks and cores, there was no significant difference between the sediment resuspended with oxygen and the sediment resuspended without oxygen. When all SOD data was combined and analyzed together, there was a significant reduction in the SOD with time. For sedOUR, there was no significant difference between the sediment resuspended with oxygen and the sediment resuspended without oxygen. Additionally, when the treatment and control data were combined, there was no significant change in the sedOUR over time for 147 hours of treatment. There was no significant change (at 95%) in concentration for any of the measured sediment quality parameters over time, thus we conclude that resuspension of the sediment, either with or without oxygen, had no effect on any sediment quality parameters. For Al, Iron, Mn, OrthoPO4, TP, COD, NO3-N+NO2-N, and TN, there was a significant change in the concentration in the positive direction over time for the treatment. For NH4-N and TOC, there was not a significant change in concentration over time. For Mn and NO3-N+NO2-N, there was a significant difference between the tank with added oxygen and the tank without added oxygen. For Mn, over the course of the treatment, there was a negative change in concentration for the tank with added oxygen, and a slight positive change in concentration over time for the tank without added oxygen. For NO3-N+NO2-N, there was a positive change in concentration over time for both with and without added oxygen. The effects on NO3-N+NO2-N were significantly different between treatment and control.

Conclusions:

The algae flotation method appeared to be a feasible method for removing algae and some nutrients from the water in tanks. The greatest removal percentages were for suspended solids, as expected, and phosphorus. The ability of the process to remove 28% of the phosphorus from the tanks is encouraging because of the inability for typical ecological processes to remove phosphorus from a water body. Further cost comparisons will be conducted to determine if the amount of nutrients removed per cost will be feasible compared with alternative methods for treating eutrophic water bodies. Funding for further studies will be sought to expand the study to a larger open system.

Overall, the rapid resuspension and oxygenation treatment method explored in this study did not appear to be an economically feasible alternative to existing long-term methods of hypolimnetic oxygenation, though resuspension of sediments without oxygenation may have potential as a reservoir sediment remediation technique. Further studies are required to investigate the economic feasibility, potential benefits, and potential negative impacts of the resuspension treatment method.

Fecal Source Characterization in Select 303 (d) Listed Streams in the Illinois River Watershed with Elevated Levels of *Escherichia coli*

Basic Information

Title:	Fecal Source Characterization in Select 303 (d) Listed Streams in the Illinois River Watershed with Elevated Levels of *Escherichia coli*
Project Number:	2013AR343B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Non-point Pollution, Methods
Key Words:	Coliphage, fecal source tracking, recreational use, bacterial indicators
Principal Investigators:	Kristen Gibson

Publications and Presentations

N/A

Arkansas Water Resources Center 104B Program Project – March 2013 through February 2014

Project Title: Fecal Source Characterization in Select 303 (d) Listed Streams in the Illinois River Watershed with Elevated Levels of *Escherichia coli*

Project Team: Kristen E. Gibson, Department of Food Science, Center for Food Safety, University of Arkansas, Fayetteville, AR

Interpretative Summary:
In Northwest Arkansas (Washington and Benton counties), several streams within the IRW have been placed on the 303(d) list for impaired waterbodies – 8 streams specifically due to elevated *E. coli* levels. Here, 500 ml water samples were collected from 23 separate sampling sites over an eleven-month period providing a total of 462 samples. Thus far, these samples have been analyzed for *E. coli* as well as coliphage in order to possibly determine origin of fecal contamination. In addition, 2,164 coliphage plaques have been isolated, and a subset of those (n = 742) have been analyzed by PCR and RT-PCR to determine coliphage type.

Introduction:
Recently, the Arkansas Natural Resources Commission (ANRC) has designated the Illinois River Watershed (IRW) as a priority watershed for the 2011-2016 NPS Pollution Management Plan. In Northwest Arkansas (Washington and Benton counties), several streams within the IRW have been placed on the 303(d) list for impaired waterbodies. As of Fall 2012, there were 13 streams—including 5 reaches of the Illinois River—on the 303(d) list for the IRW, and of these, 8 (62%) were due to elevated *E. coli* levels. Moreover, the source of fecal contamination is listed as unknown for all but one stream. Current standard methods for the evaluation of microbial water quality involve the use of generic bacterial indicators such as enterococci, fecal coliforms, and *E. coli*. However, these indicator bacteria do not provide enough information to determine the source of the fecal contamination. In order to help prevent these streams from remaining on the 303(d) list, identification of the primary origins/sources of fecal pollution is needed. The objectives of the proposed study were to: 1) collect and process water samples from 303 (d) listed streams within the IRW and 2) determine likely dominant sources of fecal contamination over multiple seasons including "off-seasons" (e.g., when recreational activity is minimal). Male-specific, ssRNA coliphage viruses (FRNA) were the primary microbial target for determination of likely fecal contamination. Overall, we collected 500 ml water samples from 23 separate sites across 8 streams during an eleven-month period on a biweekly basis beginning in May 2013 and ending in April 2014.

Methods:
Water samples (500 ml) were collected on a biweekly basis from 23 separate sites across 8 streams in the IRW beginning in May 2013 (Table 1). Samples were collected from the streams mainly by overpass using an alpha horizontal water sampler (Wildco, Yulee, FL) and then placed into sterile 500 ml Nalgene bottles. The samples were transported back to the lab in a cooler with ice packs for immediate processing. Water quality parameters were collected at the time of sampling using a Hydrolab Quanta Water Quality meter to measure temperature, conductivity, dissolved oxygen, pH, and turbidity. Additional area information including daily precipitation and mean daily water inflow for the watershed will be obtained from the Little Rock USGS reports available online. UV index will be obtained from local weather forecasts.

Table 1. 303(d) streams selected for fecal indicator monitoring.

303 (d) Stream	Reach	Contamination Source
Baron Fork	-013	Unknown
Illinois River	-023	Unknown
Clear Creek	-029	Urban Runoff
Muddy Fork	-025	Unknown
Illinois River	-028	Unknown
Osage Creek	-030	Unknown
Little Osage Creek	-933	Unknown
Spring Creek	-931	Unknown

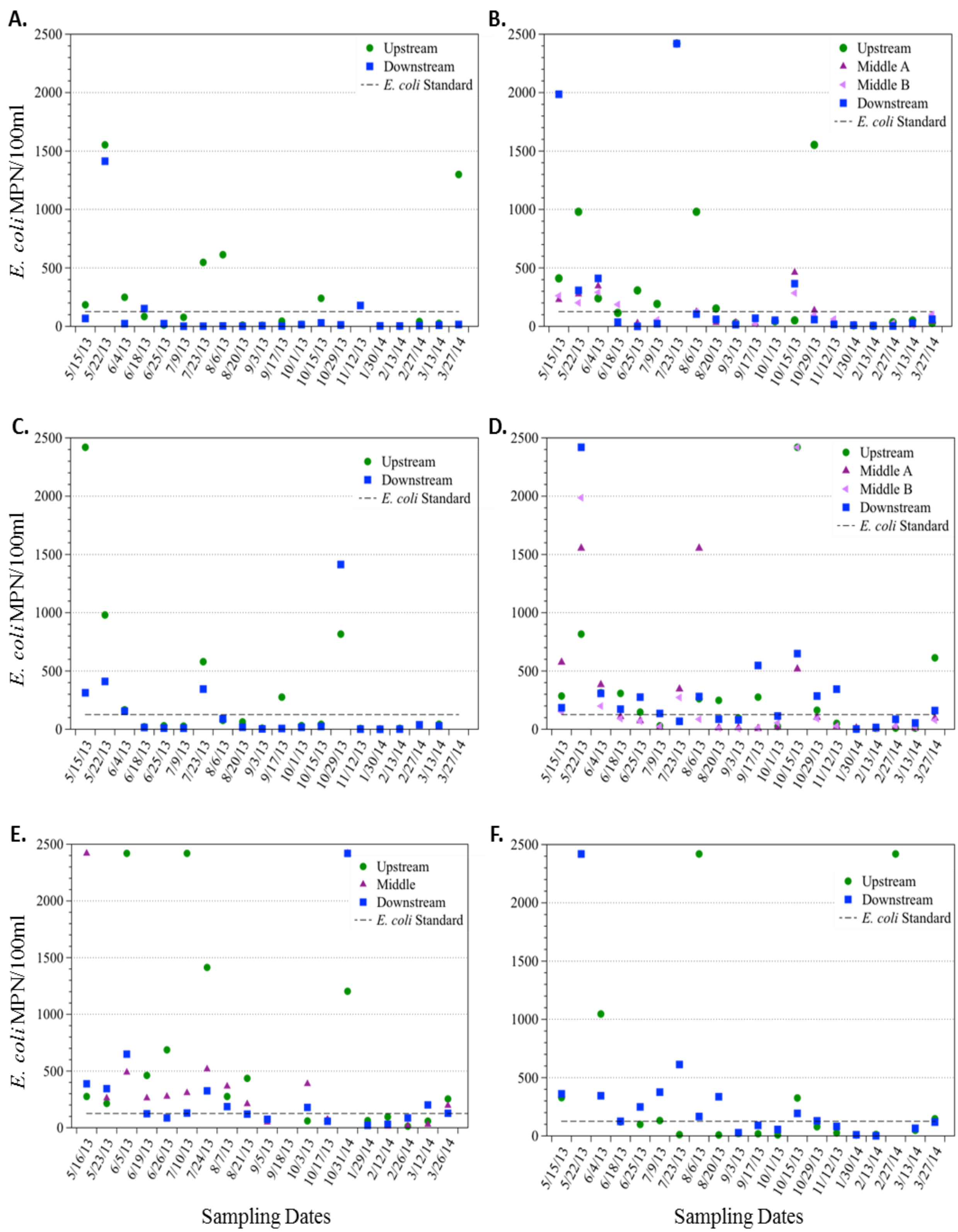
Source: www.arkansaswater.org

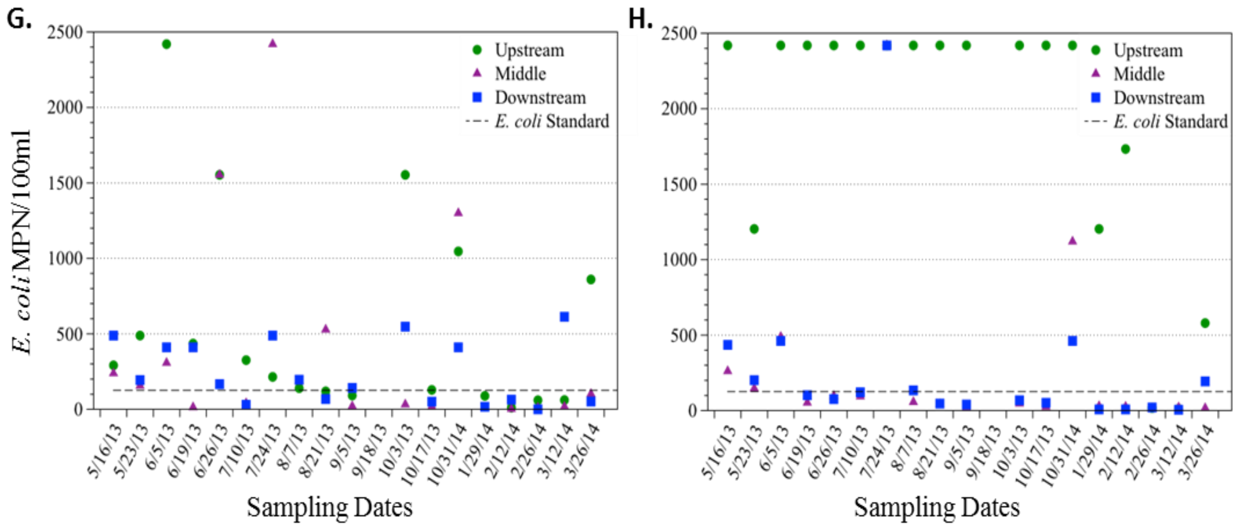
For detection and enumeration of *E. coli*, Colilert™ Quanti-tray® system (IDEXX Laboratories, Westbrook, ME) was used to determine the Most Probable Number (MPN) in each sample. A negative control containing 100 ml 0.1% peptone was analyzed by Colilert™ for each batch of samples. For quantification of FRNA and FDNA coliphage in water samples (100 ml), USEPA Method 1602 for detection of coliphage by single agar layer (SAL) procedure was used (USEPA, 2001). For selection of FRNA and FDNA coliphage, *E. coli* strain C3000 host was utilized. Following quantification by the SAL procedure, individual plaques (up to 15 from each sample) were isolated using a sterile micropipette tip, resuspended in 500 µl of SM buffer, and stored at -80°C until analysis. For nucleic acid extraction, coliphage plaque suspension (up to 6 for each sample) were incubated at 94°C for 3 min. Following extraction, the samples were analyzed by conventional PCR using FDNA specific primers, and those samples that were negative for FDNA were then analyzed by reverse transcription PCR (RT-PCR) using FRNA specific primers. Once confirmed FRNA, the samples will be analyzed to determine the specific FRNA genogroup. For detection of additional markers of fecal contamination, polyethylene glycol (PEG 8000) precipitation was performed on 200 ml of samples determined to have elevated levels of coliphage (i.e. > 50 PFU). The resulting pellet was resuspended in disodium phosphate and total nucleic acid (RNA and DNA) extraction was performed as describe in Lambertini et al. (2008). The extracted nucleic acid will be analyzed by real time PCR for the presence of human and bovine polyomaviruses as well as human adenoviruses.

Results:

At the culmination of the study, 462 samples were collected – approximately 20 samples from each sampling site. Each sample was analyzed for *E. coli*. Results for *E. coli* at each sampling site across sampling dates are shown in Figure 1A-H. Of interest, Spring Creek (IRW reach -931) upstream location had consistently elevated levels of *E. coli* (i.e. >2,419.6 MPN/ml) (Figure 1H) throughout most of the eleven-month sampling period dipping below approximately 600 MPN/100ml only twice. This particular sampling site runs through Springdale located just east of Thompson Ave and north of Backus Ave. The primary source of contamination is likely from the surrounding urban area and possibly impacted by Shiloh Memorial Park just upstream from the sampling site. Further analysis of coliphage and human specific markers will assist in better understanding the potential source. Figure 2A-B has also been provided to demonstrate the lack of agreement between levels of *E. coli* and coliphage at two example upstream sampling locations.

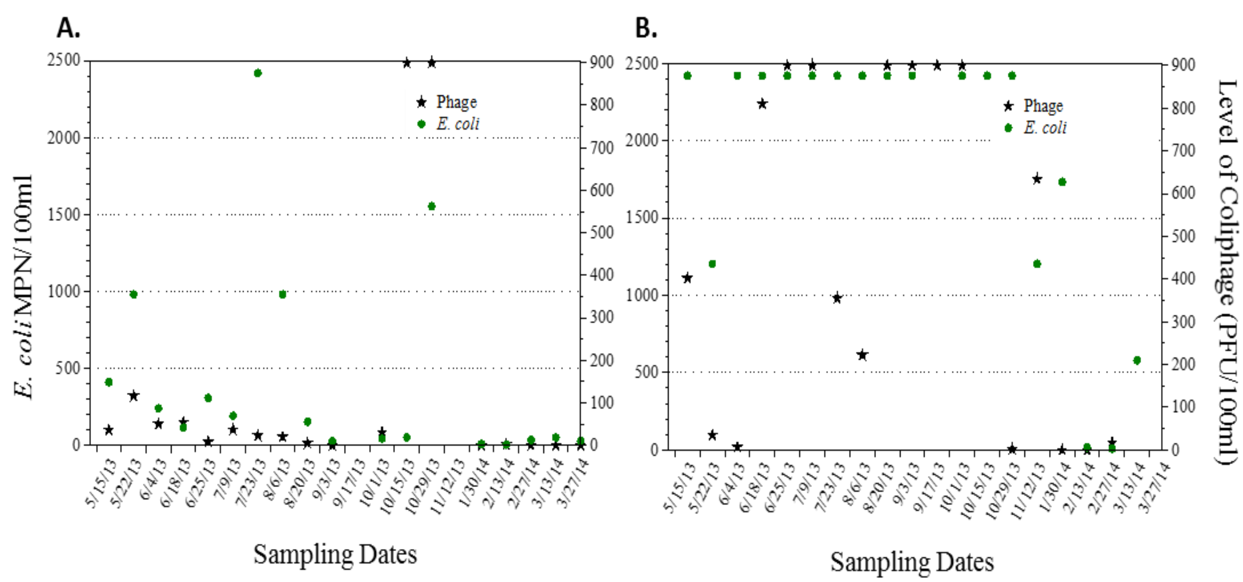
Figure 1. Levels of *E. coli* for select IRW streams over an 11-month sampling period. A = Baron Fork; B = Clear Creek; C = Illinois River 023; D = Illinois River 028; E = Little Osage Creek; F = Muddy Fork; G = Osage Creek; H = Spring Creek





Thus far, 742 coliphage plaques have been analyzed by PCR and RT-PCR to determine FDNA or FRNA status, respectively. Additionally, 38 samples have been processed by PEG precipitation and total nucleic acid has been extracted for future analysis of select fecal contamination markers. Last, we still plan to investigate how precipitation events may impact the *E. coli* levels at each of the sampling sites; however, just based on qualitative analysis of the data (Figure 1A-H), levels of *E. coli* were higher in the months that typically have lower levels of precipitation – June, July, and August.

Figure 2. Levels of coliphage and *E. coli* at two upstream sampling locations. A = Clear Creek; B = Spring Creek



Conclusions:

Eight IRW 303(d) streams were selected for fecal monitoring over an eleven-month period. During this time, most streams had *E. coli* levels exceeding the 126 MPN/100ml cut-off; however, levels seemed to be lower from November 2013 to March 2014. In addition, there was not a clear trend of decreasing levels of *E. coli* when moving from upstream to downstream locations on a single stream – only Baron Fork and Spring Creek demonstrated this trend somewhat. Last, we have generated a large library of coliphage (n = 2,164) for which a subset will be analyzed and typed in order to glean more information about potential fecal source. Overall, this study generated much needed information on the levels of *E. coli* and coliphage in impaired waterbodies due to fecal contamination in the IRW.

References:

Lambertini E., Spencer S., Bertz P., Loge F., Kieke B. and Borchardt M. 2008. Concentration of enteroviruses, adenoviruses, and noroviruses from drinking water by use of glass wool filters. Appl. Environ. Microbiol. 74:2990-2996.

USEPA, 2001. Methods 1602. Male-specific (F+) and somatic coliphage in water by single agar layer (SAL) procedure. Washington, D.C.: Office of Water, U.S. Environmental Protection Agency.

The Effect of Global Climate Change on Algal Biomass and Total Organic Carbon Concentrations in Beaver Lake

Basic Information

Title:	The Effect of Global Climate Change on Algal Biomass and Total Organic Carbon Concentrations in Beaver Lake
Project Number:	2013AR344B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Climatological Processes, Surface Water
Key Words:	Climate change, TOC, algal biomass
Principal Investigators:	Byron Winston and J. Thad Scott

Publications and Presentations

N/A

Arkansas Water Resources Center 104B Program Project – March 2012 through February 2013

Project Title: The effect of global climate change on algal biomass and total organic carbon concentrations in Beaver Lake

Project Team: Byron A .Winston, Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, AR
Thad Scott, Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, AR

Interpretative Summary:
Global Climate Change Climate change coupled with eutrophication could result in increased algal biomass in drinking water reservoirs and potentially enhance the production of disinfection by-products during the water purification process.

Introduction:
Beaver Reservoir is the drinking water source for > 250,000 people in Northwest Arkansas and a major economic engine for the entire state. Therefore, protecting water quality continues to be a top priority for Beaver Water District, the management authority for the reservoir. Global Climate Change, in addition to the traditional impairers of water quality such as nutrients and sediments, has been predicted to severely deteriorate water quality by increasing nutrient supply, algal blooms and total organic carbon concentrations in lakes. Increased TOC could enhance the production of disinfection by-products during the water purification process.

However, few studies have examined the relationship between global climate change, nutrients and increased TOC. We designed an experiment to determine if expected carbon dioxide concentrations over the next 50 years might result in elevated total organic carbon (TOC) due to increased algal nutrient use efficiency in Beaver Lake.

Methods:
Scenedesmus dimorphus, commonly found green algae at Beaver Lake, was cultivated with high nutrients at three concentrations of CO_2 250 ppm, 400 ppm and 550 ppm. The CO_2 concentrations ranged from preindustrial (250 ppm) at the lower end to concentrations expected within the next 50 years (550 ppm) at the high end. In order to fully control growing conditions, chemostats were made using 1L side arm flask and rubber stoppers. Nutrients and CO_2 were supplied to the flasks through holes in the stopper at constant rates. After 27 days, 75 ml of algae was filtered through glass fiber filters and assessed for chlorophyll a, particulate nitrogen (N), particulate carbon (C) and particulate phosphorus (P).

Results:
Algal biomass measured as chlorophyll a was significantly different across pCO_2 ($F_{2,6} = 7$, $p = 0.031$). The differences were driven by increased chlorophyll a at 400 ppm CO_2. Chlorophyll a averaged 76 ± 8 at 400 ppm and was significantly different from chlorophyll a at 250 ppm which averaged 42 ± 2 (Fig. 1a). There was no significant difference between average chlorophyll a of 56 ± 7 at 550 ppm and 400 ppm.

Algal biomass, as particulate carbon, averaged 35 ± 3 mg/L, 126 ± 14 mg/L and 59 ± 0.4 mg/L at 250 ppm, 400 ppm and 550 ppm CO_2, respectively (Fig. 1b). Biomass was significantly different across pCO_2

treatments ($F_{2,6}$ = 33, p = 0.001) but differences were driven by CO_2 at 400 ppm. Biomass was significantly greater at 400 ppm CO_2 relative to 250 ppm CO_2 (p = 0.001) and 550 ppm CO_2 (p = 0.003). There was no significant difference in biomass between 250 ppm CO_2 and 550 ppm CO_2. Biomass

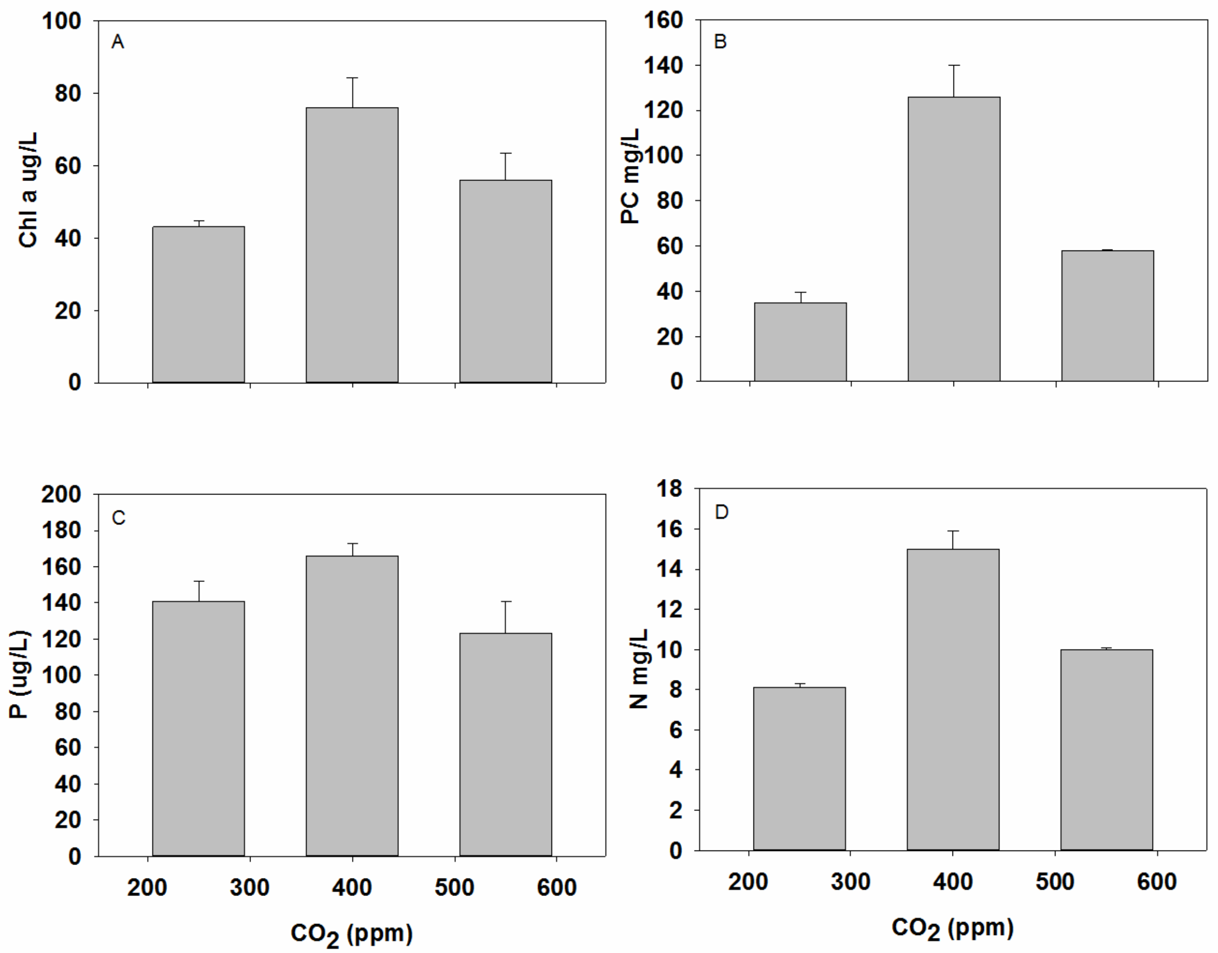


Figure 1. Variations in algal biomass algal biomass and nutrient content across CO_2 treatments.

Nutrients: Particulate phosphorus averaged 141 ± 11 ug/L, 166 ± 7 ug/L and 123 ± 15 ug/L at 250 ppm, 400 ppm and 550 ppm CO_2, respectively (Fig. 1c). There were no significant differences in P uptake across CO_2 treatments ($F_{2,6}$ = 3, p = 0.102). Particulate N was significantly different across CO_2 treatments ($F_{2,6}$ = 34, p = 0.001). N averaged 8 ± 0.2 mg/L, 15 ± 1.0 mg/L and 10 ± 0.1 mg/L at 250 ppm, 400 ppm and 550 ppm CO_2 respectively (Fig. 1d). Significant differences in N occurred between 250 ppm and 400 ppm ($p < 0.001$) and 400 ppm and 550 ppm (p = 0.003). There was no significant difference in N between 250 ppm and 550 ppm CO_2 (p = 0.100).

Algal Stoichiometry: Both the C:P and C:N molar ratio were significantly different across CO_2 levels (p = 0.019 and 0.001) respectively. C:P ratio averaged 665 ± 27, 2005 ± 149, 1298 ± 154 at 250 ppm, 400 ppm and 550 ppm CO_2 respectively (Fig. 2a). C:P ratio at 250 was significantly lower than C:P at 400 ppm CO_2 (p = 0.018) and at 550 ppm CO_2 (p = 0.059). C:P ratio was not significantly different at 400 ppm CO_2 relative to 550 ppm CO_2. The C:N ratio was significantly different across CO_2 treatment ($F_{2,6} = 50$, $p = 0.001$) and all comparisons were different from each other (all $p < 0.05$, Fig. 2b).

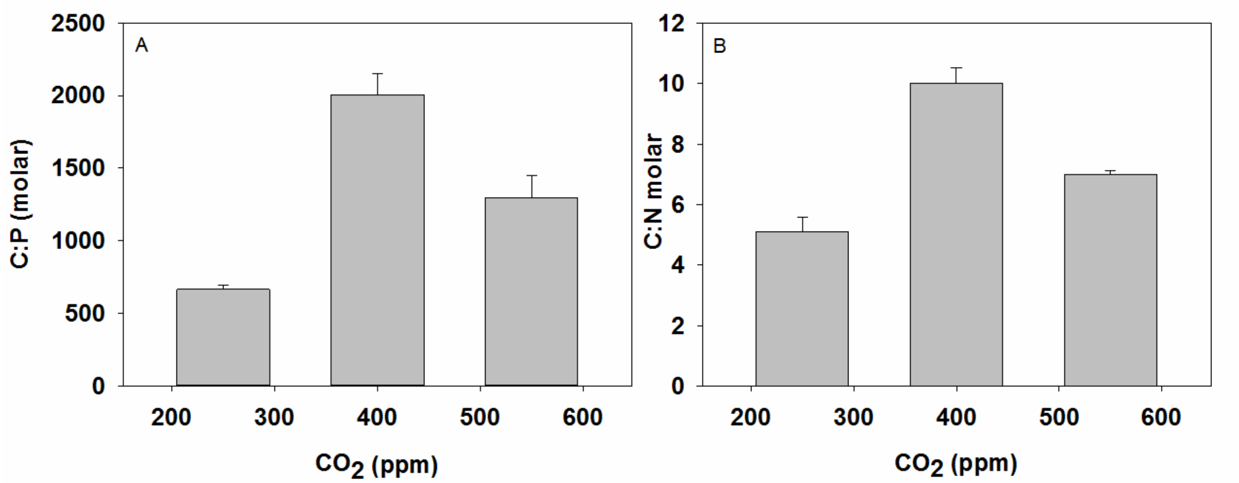


Figure 2. Variations in algal nutrient stoichiometry across CO_2 treatments.

Conclusions:

In conclusion, CO_2 at the highest level (550 ppm) did not cause a significant increase in algal biomass or algal stoichiometry. Significant differences were observed in biomass, particulate phosphorus and particulate nitrogen but differences were driven by CO_2 at 400 ppm. Based on our experiment, predicted CO_2 concentration in the next 50 years might not increase total organic carbon concentrations in Beaver Lake.

Economics of On-Farm Reservoirs Across the Arkansas Delta Region: A Conjunctive Management Approach to Preserving Groundwater and Water Quality

Basic Information

Title:	Economics of On-Farm Reservoirs Across the Arkansas Delta Region: A Conjunctive Management Approach to Preserving Groundwater and Water Quality
Project Number:	2013AR345B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Economics, Agriculture, Conservation
Descriptors:	
Principal Investigators:	Kent Kovacs, Kristofor Brye, Jennie Popp, and Eric Wailes

Publications and Presentations

1. Kovacs, K., E. Wailes, G. West, J. Popp, and K. Bektemirov. In review. Optimal Spatial-Dynamic Management of Groundwater Conservation and Surface Water Quality with On-Farm Reservoirs. Journal of Agricultural and Applied Economics.
2. Kovacs, K. 2014. Management of Groundwater and Surface Water Quality with On-Farm Reservoirs. Selected, Southern Agricultural Economics Association Annual Meeting, Dallas, TX.
3. Kovacs, K. 2013. Preserving the Quantity and Quality of Water in the Arkansas Delta. Selected Poster, Arkansas Water Resources Center Annual Watershed and Research Conference, Fayetteville, AR.
4. Bektemirov, K. 2013. Preserving the Quantity and Quality of Water in the Arkansas Delta. Selected Poster, 57th Annual Rural Life Conference, Pine Bluff, AR.
5. Bektemirov, K. 2014. Management of Groundwater and Surface Water Quality with On-Farm Reservoirs" Selected, Southern Regional Science Association Annual Meeting, San Antonio, TX.

Arkansas Water Resources Center 104B Program Project – March 2012 through February 2013

Project Title: Economics of On-Farm Reservoirs Across the Arkansas Delta Region: A Conjunctive Management Approach to Preserving Groundwater and Water Quality

Project Team: Kent Kovacs, Department of Agricultural Economics and Agribusiness, Division of Agriculture, University of Arkansas, Fayetteville, AR
Eric Wailes, Department of Agricultural Economics and Agribusiness, Division of Agriculture, University of Arkansas, Fayetteville, AR
Jennie Popp, Department of Agricultural Economics and Agribusiness, Division of Agriculture, University of Arkansas, Fayetteville, AR
Kristopher Brye, Department of Crop, Soil, and Environmental Sciences, Division of Agriculture, University of Arkansas, Fayetteville, AR

Interpretative Summary:
We examine the joint management of groundwater quantity and surface water quality using on-farm reservoirs with a spatial-dynamic model of farm profit maximization in the Arkansas Delta. Several policies for alleviating groundwater depletion and enhancing water quality are compared to find which strategies are cost-efficient for the conservation goals. The best policy for a significant intervention is to cost share on reservoir construction because both quality and quantity goals are achieved cost effectively at a modest redistribution of income.

Introduction:
This report describes an empirical analysis of the management of groundwater and surface water quality to maximize farm profits by considering on-farm reservoirs with tail-water recovery that capture runoff leaving the field to provide irrigation later in the season and to reduce the pollutants that leave the farm. Policy instruments to lower groundwater withdrawals or non-point agricultural pollution are compared for their ability to cost-effectively achieve both water quantity and quality goals.

The application of this model is the farming region of the Arkansas Delta which had more than four million acres of irrigated cropland in 2007, principally based on groundwater pumping that has significantly depleted the alluvial aquifer (Schaible and Aillery, 2012). Spatial groundwater flow occurs between sites in response to the distance from cones of depression formed by the well pumping. Pollutant loading are estimated by calculating the contaminated water leaving each site and routing this downstream where some of the pollutant may be filtered or additional pollutant added. The planner's decision about where to place reservoirs and the type of crops grown is influenced by the farm profits, groundwater withdrawals, and the pollutant loadings associated with each site.

Methods:
We track the cumulative amount of land in use j for n land types for each of the major crops in the region (irrigated corn, cotton, rice, irrigated soybean and non-irrigated soybean) at the end of period t with L_{ij} (t) site i. Farmers can choose to switch land out of rice, corn, and cotton into irrigated soybeans in response to a growing water shortage, or land out of dry land soybeans into irrigated soybeans for the higher yield, and this is tracked with the variable IS_{ij} (t). Each period, the amount of irrigated land in use j is reduced by the amount of land converted to on-farm reservoirs or switched into non-irrigated soybean production. The cumulative amount of land in on-farm reservoirs by the end of period t is the amount of land in

reservoirs in earlier periods and the sum of the amount of land added to reservoirs from all land uses *j* during period *t*.

Irrigation demand varies by crop and is given by wd_j, representing average annual irrigation needs excluding natural rainfall. The variable $AQ_i(t)$ is the amount of groundwater (acre-feet) stored in the aquifer beneath site *i* at the end of the period *t*. The amount of water pumped from the ground is $GW_i(t)$ during period *t*, and the amount of water pumped from the on-farm reservoirs is $RW_i(t)$. The natural recharge (acre-feet) of groundwater at a site *i* from precipitation, streams, and underlying aquifers in a period is nr_i and is independent of crops grown on site *i*.

Further, we define p_{ik} as the expected proportion of the groundwater in the aquifer that flows underground out of site *i* into the aquifer of site *k* when an acre-foot of groundwater is pumped out of site *k*, where p_{ik} is a negative quadratic function of the distance and the saturated thickness between sites *i* and *k*. The amount of water leaving site *i* is then $\sum_{k=1}^{m} p_{ik} GW_k(t)$. The cost of pumping an acre-foot of groundwater to the surface at site *i* during period *t* is $GC_i(t)$. Pumping costs depend on the cost to lift one acre-foot of water by one foot using a pump, c^p, the initial depth to the groundwater within the aquifer, dp_i, and the capital cost per acre-foot of constructing and maintaining the well, c^c.
Several economic parameters are needed to complete the formulation. The price per unit of the crop is pr_j and the cost to produce an acre of the crop excluding the water use costs is ca_j, which depend on the crop *j* and are constant in nominal terms. The yield of crop *j* per acre is y_{ij} at site *i* and are constant meaning no productivity growth trend. The net value per acre for crop *j* is then $pr_j y_j - ca_j$ excluding differential water pumping cost between well and reservoir water, and the reservoir construction costs. The discount factor to make values consistent over time is δ_t. Other costs constant in nominal terms include the annual per acre cost of constructing and maintaining a reservoir, c^r, and the cost of pumping an acre-foot of water from the tail water recovery system into the reservoir and from the reservoir to the field plus the capital cost per acre-foot of constructing and maintaining the pump, c^{rw}.

Results:
Table 1 summarizes crop allocations, water conditions, reservoir adoption and farm profits with and without reservoirs over time when profit maximization is the only objective. In scenarios where no reservoir construction is permitted (‘without reservoirs’) on the roughly 1.2 million acres of available cropland, nearly 46 percent (543,000 acres) of the land shifts out of rice, irrigated soybeans and non-irrigated soybeans and into irrigated corn by 2022. This reallocation from 2012 to 2022 increases annual farm net returns by $25 million, drops annual groundwater irrigation use by 436,000 acre feet, and the aquifer declines to a little less than 71 million acre feet. However annual losses of nutrients from farm practices increase substantially, nitrogen by 76% and phosphorus by 112%, while sediment increased 18%. Between 2022 and 2042 a smaller percentage of additional acreage move out of rice and irrigated soybean and into irrigated corn and non-irrigated soybean. This further reduces annual groundwater irrigation use by 70,000 acre feet, and the final aquifer level is 54.6 million acre feet. By 2042, annual sediment exports increase overall by 18% and annual phosphorus exports nearly double compared to 2012. These increases are experienced nearly uniformly in the watersheds with the exception of far lower areas of the L’Anguille and far upper reaches of the Big (Fig. 1a). Losses in revenue and higher costs of irrigation cause annual farm net returns to fall 12.5% from 2022, but the annual net returns are still greater than in 2012.

Table 1. Initial, 2022, and 2042 crop allocations, water conditions, reservoir adoption, and farm profits with and without reservoirs. The objective includes no buffer value for the groundwater and no water quality value.

Crop and water conditions	Initial, 2012	Without reservoirs		With reservoirs	
		2022	2042	2022	2042
Rice (thousand acres)	356	81	59	169	166
Irrigated corn (thousand acres)	52	595	604	515	516
Irrigated cotton (thousand acres)	79	79	78	79	79
Irrigated soybeans (thousand acres)	530	382	378	353	351
Non-irrigated soybeans (thousand acres)	170	50	68	0	0
Reservoirs (thousand acres)	0	0	0	71	75
Annual reservoir water use (thousand acre-feet)	0	0	0	797	833
Annual groundwater use (thousand acre-feet)	1,846	1,410	1,340	768	726
Aquifer (thousand acre-feet)	79,633	70,896	54,624	77,133	73,057
Annual phosphorus exports (tons)	580	1,017	1,036	737	738
Annual nitrogen exports (tons)	1,596	3,390	3,463	2,458	2,429
Annual sediment exports (tons)	57,229	67,296	67,631	45,830	45,773
Annual farm net returns (millions in 2012$)[1]	111	136	119	150	146
30yr PV farm net return (millions in 2012$)[1]	--	2,616		2,959	

[1] The groundwater buffer value of the aquifer and the water quality value are not counted in the farm net returns.

Allowing reservoir construction reduces nutrient and sediment loss, slows aquifer depletion, and improves annual farm net returns compared to the 2012 and the 'without reservoir' conditions. Even though available production acres fall by 75,000 acres by 2042 to create reservoirs (many of which are placed in the Lower White watershed), annual farm net returns are higher with reservoirs because more acreage remains in profitable rice, low revenue non-irrigated soybeans are eliminated, and the costs associated with pumping water from the aquifer are greatly reduced. While groundwater levels continue to fall, groundwater levels only decrease by 8% when reservoirs are allowed compared to 31% without reservoirs. Similarly, percentage increases in annual phosphorus and nitrogen loadings are much lower with reservoirs compared to without reservoirs (Fig. 1b) because more acreage remains in rice, and sediment loadings actually decrease with reservoirs compared to 2012.

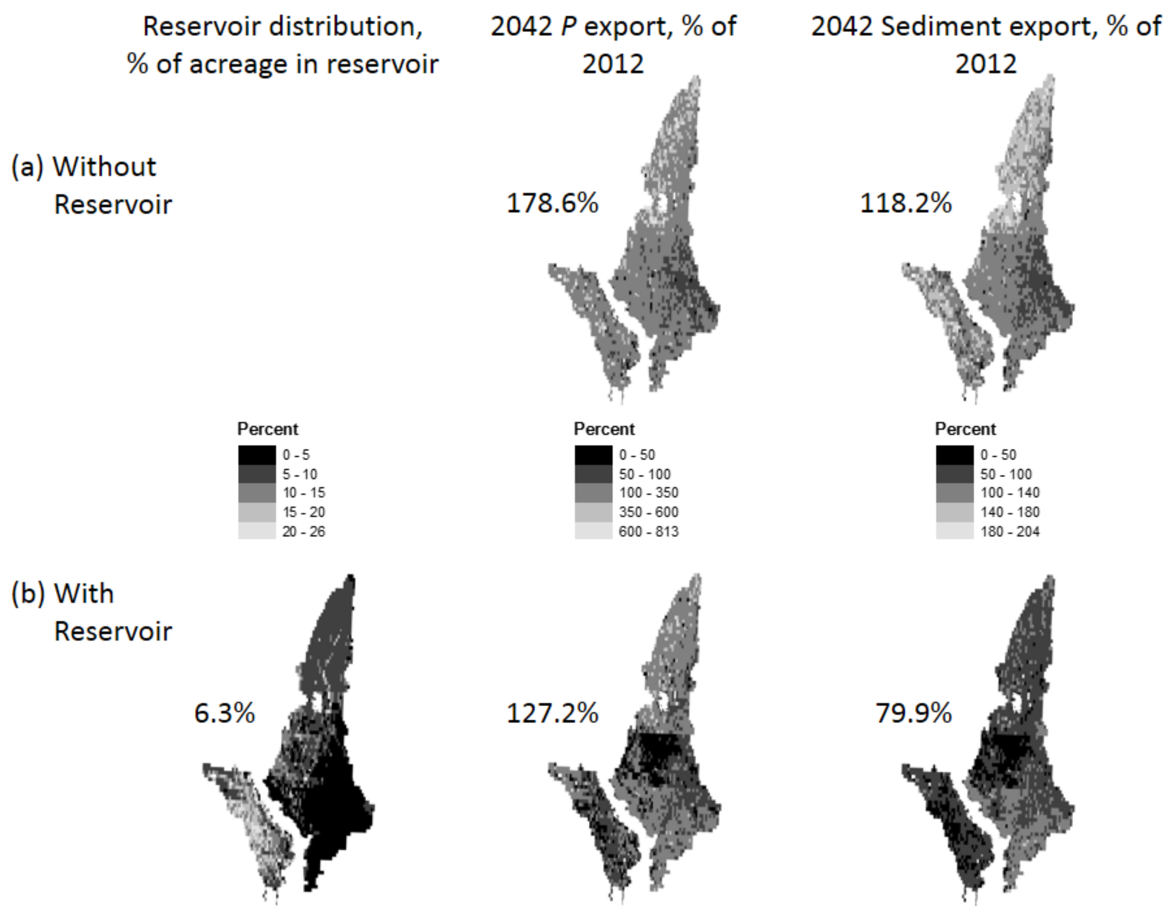


Figure 1. Reservoir locations and the change in phosphorus and sediment exports under the cases without and with reservoirs. The model runs do not have groundwater buffer value or water quality value. The numbers by the side of each map indicate study area averages.

Conclusions:

The results suggest that the joint management of groundwater and surface water with on-farm reservoirs can increase social benefits. Currently, the focus for building reservoirs with tail-water recovery is to conserve groundwater resources; however, with proper management of the reservoirs, there is the opportunity to significantly improve water quality across the agricultural landscape. When only pure profit motive is considered, the use of reservoirs allows farm profits to rise, final aquifer levels to increase, and pollutant loadings to decrease. Thus, the construction of reservoirs both increase farm profit and enhance conservation.

References:

Schaible, G.D., and M.P. Aillery. Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands. Washington, DC: U.S. Department of Agriculture, Economic Research Service, EIB-99, September 2012.

Arkansas Water Resources Center Information Transfer Program

Basic Information

Title:	Arkansas Water Resources Center Information Transfer Program
Project Number:	2013AR340B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Information Transfer
Focus Category:	Education, Water Quality, Water Use
Key Words:	Conference, Newsletters, Web Interface, Citizen Science
Principal Investigators:	Brian Haggard

Publications and Presentations

1. Patterson, S.D., B.E. Haggard, and M.E. Boyer. 2013. Ecological Design in the Ozarks – Workshop and Lake Francis Charrette. Arkansas Water Resources Center, Fayetteville, Arkansas. Technical Publication MSC 368, 25 pp.
2. Massey, L.B., J.A. McCarty, M.D. Matlock, A.N. Sharpley, and B.E. Haggard. 2013. Water Quality Monitoring for Selected Priority Watersheds in Arkansas, Upper Saline, Poteau and Strawberry Rivers. Arkansas Water Resources Center, Fayetteville, Arkansas. MSC Publication 369, 81 pp.

Information Transfer Program Introduction

The dissemination of information is one of the main objectives and missions of the Arkansas Water Resources Center (AWRC). AWRC sponsors an annual conference held in Fayetteville, AR. The 2013 conference focused on "104B Research Projects and Impacts and Ecological Design in the Ozarks". The conference drew approximately 120 researchers, students, agency personnel, and interested citizens from Arkansas and Oklahoma to hear about these topics and other research in water issues throughout the State. Access to the conference program can be found here (http://www.uark.edu/depts/awrc/ conference.html).

AWRC also sponsored a three-day workshop and charrette titled "Ecological Design in the Ozarks". This event brought together over 30 individuals with diverse backgrounds and expertise including students, landscape architects, engineers, water quality specialists, ecologists, kayakers, and other interested individuals. This group of people spent three days learning, brainstorming, and designing future possibilities for Lake Francis, a small impoundment on the Illinois River on the border of Arkansas and Oklahoma. More information about the activities and design proposals from this workshop can be found online (www.uark.edu/depts/awrc) as technical publication MSC 368.

AWRC maintains a technical library containing over 900 titles, many of which are available online. This library provides a valuable resource utilized by a variety of user groups including researchers, students, regulators, planners, lawyers, and citizens. Many of the AWRC library holdings have been converted to electronic PDF format for easy access from the AWRC website at www.uark.edu/depts/awrc. AWRC is continuing to build its online database by adding archived documents from the library to electronic format as well as by adding all new publications to the website.

The AWRC maintains an active website that not only provides access to technical publications, but also includes information about current USGS 104B projects and the AWRC Water Quality Laboratory. Additionally, AWRC produces a monthly electronic newsletter that's emailed to the AWRC listserv and available on the AWRC website. AWRC is also on facebook with 123 "likes" and on Twitter. By utilizing multiple media outlets, AWRC is able to disseminate information rapidly and effectively to stakeholders across the State.

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	10	0	0	0	10
Masters	3	0	0	0	3
Ph.D.	1	0	0	0	1
Post-Doc.	1	0	0	0	1
Total	15	0	0	0	15

Notable Awards and Achievements

Grace Richardson, MS Student, was recognized for an overall early career award. She was also selected as 1 of 14 winners nationwide for New Faces of Engineering by DiscoverE, an organization that works with major engineering professional societies to publicize the engineering profession.

Publications from Previous Years

2008AR191B ("Spatial and historical distribution of Geosmin and MIB producers in Beaver Reservoir, northwest Arkansas")

Winston, B., S. Hausmann , J. Escobar, and W.F. Kenney. 2014. A Sediment Record of Trophic State Change in an Arkansas (USA) Reservoir. Journal of Paleolimnology. (51):393-403.

2010AR252B ("Denitrification, internal N cycling, and N retention in river impoundment reservoirs")

Scott, J.T., and E.M. Grantz. 2013. N_2 Fixation Exceeds Internal Nitrogen Loading as a Phytoplankton Nutrient Source in Perpetually Nitrogen-Limited Reservoirs. Freshwater Science. (32): 849-861.

2012AR335B ("Preparing drinking water utilities on Beaver Lake reservoir to meet disinfection by product regulations: The impact of continued nutrient enrichments")

Mash, C.A., B.A. Winston, D.A. Meints II, A.D. Pifer, J.T. Scott, W. Zhang, and J.L. Fairey. 2014. Assessing trichloromethane formation and control in algal-stimulated waters amended with nitrogen and phosphorus. Journal of Environmental Science: Processes and Impacts. DOI: 10.1039/c3em00634d.

Pifer, A.D. and J.L. Fairey. 2013. Suitability of organic matter surrogates to predict trihalomethane formation in drinking water source. Journal of Environment Engineering Science. (31)117-126. DOI: 10.1089/ees.2013.0247.

2012AR336B ("Development and implementation of nutrient runoff reduction measures for poultry houses")

Rogers, C.W., A.N. Sharpley, B.E. Haggard, and J.T. Scott. 2013. Phosphorus Uptake and Release from Submerged Sediments in a Simulated Stream Channel Inundated with a Poultry Litter Source. Water, Air, and Soil Pollution. (224):1361-1370.